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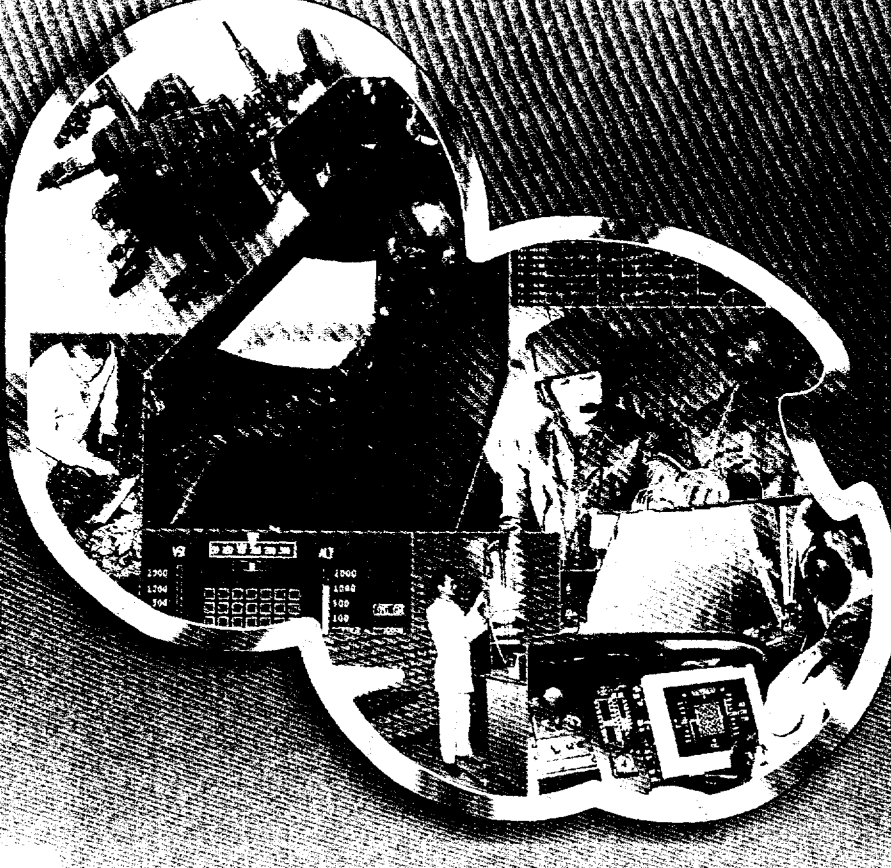
Preliminary Assessment of Stroboscopic Shutter Glasses on Motion Sickness in Helicopter Passengers

By Art Estrada



Warfighter Performance and Health Division

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14. ABSTRACT
This report presents the results of preliminary tests conducted by the USAARL of two sets of stroboscopic shutter glasses (at 4Hz and 8 Hz) proposed as a countermeasure for motion sickness. The purpose was to examine the mission applicability and product potential of the glasses and to gain support for their inclusion in future USAARL motion sickness studies. Six participants experienced two flights in the cabin of a Black Hawk helicopter: the first flight with shutter glasses and the second without them. Following each flight, each participant filled out a motion sickness questionnaire and provided subjective feedback. This preliminary testing of the shutter glasses was conducted to determine their worthiness of further study. The testing was deliberately limited with no intentions of drawing firm conclusions as to the shutter glasses' efficacy. Although the effectiveness of the shutter glasses as a countermeasure for motion sickness is not implied by this test, the results did indicated that shutter glasses, particularly the 8 Hz device, demonstrated promise and should be explored as a non-pharmacological motion sickness prevention strategy.

15. SUBJECT TERMS
Stroboscopic, shutter technology, motion sickness, airsickness

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Introduction

This report presents the results of the preliminary testing of two sets of stroboscopic shutter glasses (at 4 Hz and 8 Hz) proposed as countermeasures for motion sickness in helicopter passengers. MacNaughton, Incorporated, of Beaverton, Oregon (Appendix A), having a material transfer agreement with the U.S. Army Aeromedical Research Laboratory (USAARL), supplied the shutter glasses used in this effort. They maintain a licensing agreement with the National Aeronautics and Space Administration (NASA) for the production of the stroboscopic shutter glasses. The purpose of the tests in the USAARL JUH-60 Black Hawk helicopter was to examine the mission applicability and product potential of the glasses.

The USAARL has conducted research into motion sickness mitigation strategies for the mounted Soldier and remains interested in novel, non-pharmacological countermeasures for possible inclusion in future motion sickness studies. The preliminary testing of the shutter glasses was performed to help determine if the shutter glasses held any promise of efficacy and whether or not they should be included in future USAARL motion sickness studies.

Background

Dizziness, nausea, vomiting, drowsiness, pallor, sweating, and overall malaise that are triggered by travel in a boat, car, train, or plane all fall into the category of motion sickness (Lawther and Griffin, 1988). Motion sickness has been well known for thousands of years. Ancient seafaring nations were very familiar with this malady. This problem has become increasingly prevalent in the modern world with the development of many forms of vehicular travel. The syndrome appears to arise from a disturbance in the vestibular apparatus, organs used to maintain balance and sense orientation and movement. The most widely accepted theory concerning the cause of motion sickness focuses on sensory mismatch between the visual and vestibular systems (Eyeson-Annan et al., 1996). For example, passengers on cruise ships are far more likely to get seasick when below deck because their vestibular apparatus detects motion while their visual system does not (Gordon et al., 1994). Standard advice for such seasickness is to go up on deck where vestibular and visual inputs agree. Similarly, studies have shown that children are less likely to become car sick when elevated in a seat that provides a good outside view (Fischer, 1998).

Melvill-Jones and Mandl (1981), in a research project exploring adaptation of the vestibulo-ocular reflex, employed optically reversing prisms which induced motion sickness symptoms. They discovered what they termed a "particularly interesting" finding: "none of the subjects ever experienced nausea or associated symptoms" in stroboscopic light (strobe-light conditions). The results of a study by Reschke, Somers, and Ford (2006), comparing the efficacy of strobe lighting and shutter glasses (both at 4 Hz) as a treatment for motion sickness, were very similar to those of Melvill-Jones and Mandl. Reschke, Somers, and Ford report that stroboscopic illumination, either by ambient illumination or by shutter glasses, reduced the severity of motion sickness symptoms and "appears to be an effective countermeasure where retinal slip is a significant factor in eliciting motion sickness due to either self- or surround-motion." A review of these studies provides compelling evidence that stroboscopic technology may provide a method of preventing motion sickness in the mounted warfighter.

Methods

Before the shutter glasses were tested, each device was subjected to frequency testing to ensure proper shutter rates. Conducted by members of the USAARL Vision Science Branch, the tests were performed using a photo detector connected to an oscilloscope which determined shutter frequency. Both devices, the 4 Hz and 8 Hz models, averaged sustained shutter rates within 0.10 Hz of their requisite frequency.

This effort was originally determined to be exempt from Army Regulation 70-25, Use of Volunteers as Subjects of Research by the USAARL Human Use Committee. As such, each participant was only required to sign a Request to Test document prior to his or her participation indicating that they were fully informed of the test procedures. Due to several unanticipated requests for the results of this preliminary assessment by others interested in stroboscopic technologies, the author sought permission to publish the findings. Each participant was informed of the intent to publish and each participant consented in writing to allow the publication of these preliminary findings.

Subjects

Six USAARL personnel (non-aviator, research staff members) responded to an organization-wide email solicitation and volunteered to participate in this test.

Test design

The test design (Table 1) required that all participants wear the shutter glasses during their first flight and therefore, was not balanced. Recall that this effort was a preliminary test of the glasses' potential, not a scientific evaluation of the glasses' efficacy. Therefore, due to the limited goal of this test, no balancing of the test conditions was conducted. It was more important to allow the participants to provide their subjective assessments of the devices under a condition which was completely uncontaminated by any previous flight experiences that day. Although not scientific, comparisons with the data from the second flight (without the glasses) two hours later, does provide interesting comparisons.

Table 1.
Test design.

	Groups	*Flight 1 0930*	*Land 1000*	*Shutdown 1000-1200*	*Flight 2 1200*	*Land 1230*
Random Assignment	4 Hz	Perform reading tasks with glasses	Complete MSQs† and Subjective Surveys	Lunch	Perform reading tasks without glasses	Complete MSQs† and Subjective Surveys
	8 Hz					

† MSQ = Motion Sickness Questionnaire

Sample size

A sample size of six, three wearing 4 Hz glasses and three wearing 8 Hz glasses, was deemed appropriate for the goal of achieving a preliminary test of the glasses but most certainly was insufficient to achieve statistical power or meet scientific rigor.

Data collection tools

MSQ

Subjective motion sickness symptoms were measured using a written version of the MSQ (Appendix B) (Kellogg, Kennedy, and Graybiel, 1965). The MSQ is a self-report form consisting of 28 items (symptoms) that are rated by the participant in terms of severity on a 4-point scale or with yes-no answers. Responses from the MSQ were entered into a scoring program that automatically scored the entries for nausea, oculomotor disturbance, disorientation, and total motion sickness symptom score. Nausea scores are derived from the self-assessments of general discomfort, increased salivation, sweating, nausea, difficulty concentrating, stomach awareness, and confusion. Oculomotor disturbance scores are derived from self-assessments of general discomfort, fatigue, headache, eye strain, difficulty focusing and concentrating, and blurred vision. Disorientation scores combine reports of focusing difficulties, nausea, fullness of the head, blurred vision, dizziness with eyes open and/or closed, and vertigo. The total symptom severity score is an aggregate of all of the symptoms. This questionnaire took approximately 5 minutes to administer.

Shutter Glasses Subjective Survey

This 5-question survey instrument (Appendix C) was used to gain insight into user opinions regarding the mission applicability and product potential of the glasses.

Procedures

The six participants experienced two flights as passengers seated in the cabin of the USAARL Black Hawk helicopter: the first with shutter glasses and the second without them. Both flights occurred on the same day and were separated by approximately two hours and lunch (Table 1). The flight profile (Figure 1) included straight and level flight, hovers, turns, and ascents and descents at varying rates and speeds. Note that no aircraft maneuvering or power limitations were ever exceeded during the flights. Each flight lasted approximately 20 minutes. A detailed flight profile is included in Appendix D. The flight profile, which was practiced numerous times prior to this study, has been used in a previous airsickness countermeasures study (Estrada et al., 2007). To minimize variation, all flights were performed by the same research aviator at the aircraft controls.

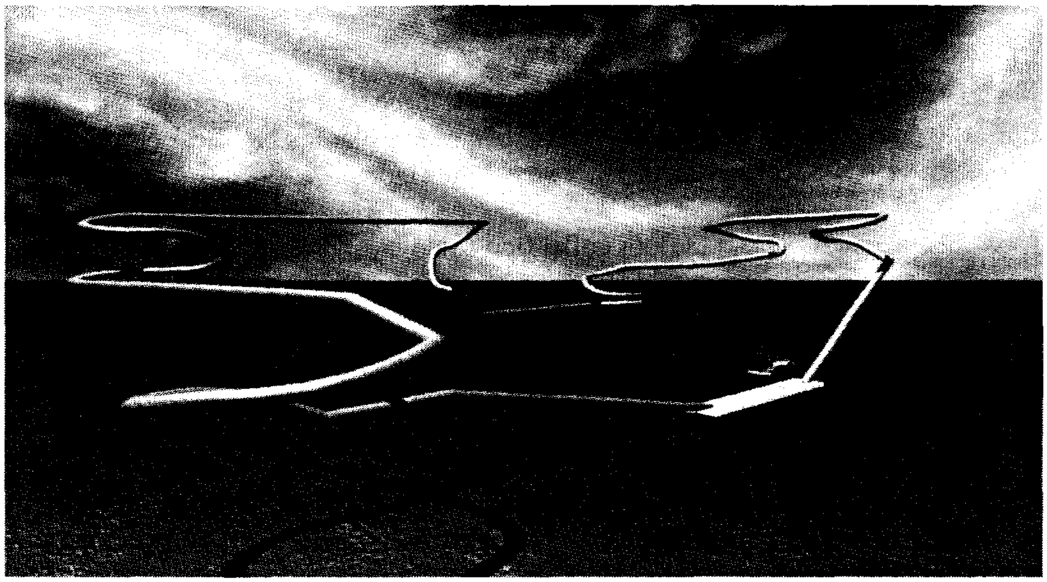

Figure 1. Flight profile.

Each participant performed reading tasks, such as reading from the aircraft checklist, operator's manual, and aviation maps, during each flight. Participants were instructed to read aloud from the material provided in a notebook. Notebook pages were lettered A through E (Appendix E), and each reading task was assigned by letter by the principal investigator/non-flying pilot in a semi-random manner. The participant read the assigned page as the non-flying pilot assured compliance and accuracy.

Data collection

Following each flight, each participant was asked to fill out a motion sickness questionnaire (MSQ) (Appendix B). In addition, each participant was requested to provide subjective feedback via the Shutter Glasses Subjective Survey (Appendix C) as to the glasses' mission applicability and product potential of the glasses.

Data analysis

As alluded to earlier, the sample was too small to employ inferential statistics; therefore, the data is presented descriptively for examination. No statistical significance is implied by the following discussion of noted differences. The descriptive statistics were produced using SPSS® 12.0.

Results and discussion

MSQ

The 28 responses on this questionnaire (Appendix B) were automatically scored by a computer program developed by A. Higdon of the USAARL. The variables used from this test include scores for nausea, oculomotor disturbance, disorientation, and a score for total motion sickness symptom severity.

Comparing conditions: glasses and no glasses

When comparing the glasses (4 Hz *and* 8 Hz versions together) versus no glasses conditions, differences were noted. Figure 2 shows that the average nausea and total symptom severity scores were lower with the glasses on than with them off (14.3 vs. 25.4 and 13.7 vs. 14.3, respectively). On the other hand, the glasses condition produced higher average scores for oculomotor disturbance (8.8 vs. 3.7) and disorientation (13.9 vs. 9.2). These findings are not surprising as the visual system is the most important sensory system for maintaining equilibrium and orientation (Headquarters, Department of the Army, 2000). In addition, recall that a number of symptoms are combined to derive the MSQ oculomotor disturbance and disorientation scores. (See MSQ on page 3). An examination of Table 2, containing the frequencies in which MSQ symptoms were reported, reveals that many of the symptoms factored to derive these two scores were reported only when the glasses were worn and especially with the 4 Hz model.

In their present prototypical design, the glasses appear to affect some wearers' vision, specifically causing difficulty focusing, eye strain and blurred vision. This may have affected their focal and ambient vision. According to Gillingham and Previc (1993), while focal vision is not primarily involved with orienting the individual in the environment, it certainly contributes to conscious percepts of orientation, such as those derived from judgments of distance and depth and those obtained from reading (p. 17). Ambient or peripheral vision is primarily involved with one's orientation within an environment and is largely independent of focal vision. Hence, one can fully occupy focal vision with reading while simultaneously obtaining sufficient orientation cues with their peripheral vision (Gillingham and Previc, p. 18). Therefore, it is reasonable to expect that any device that impairs or negatively affects visual perception can disturb visual/motor coordination and affect spatial orientation.

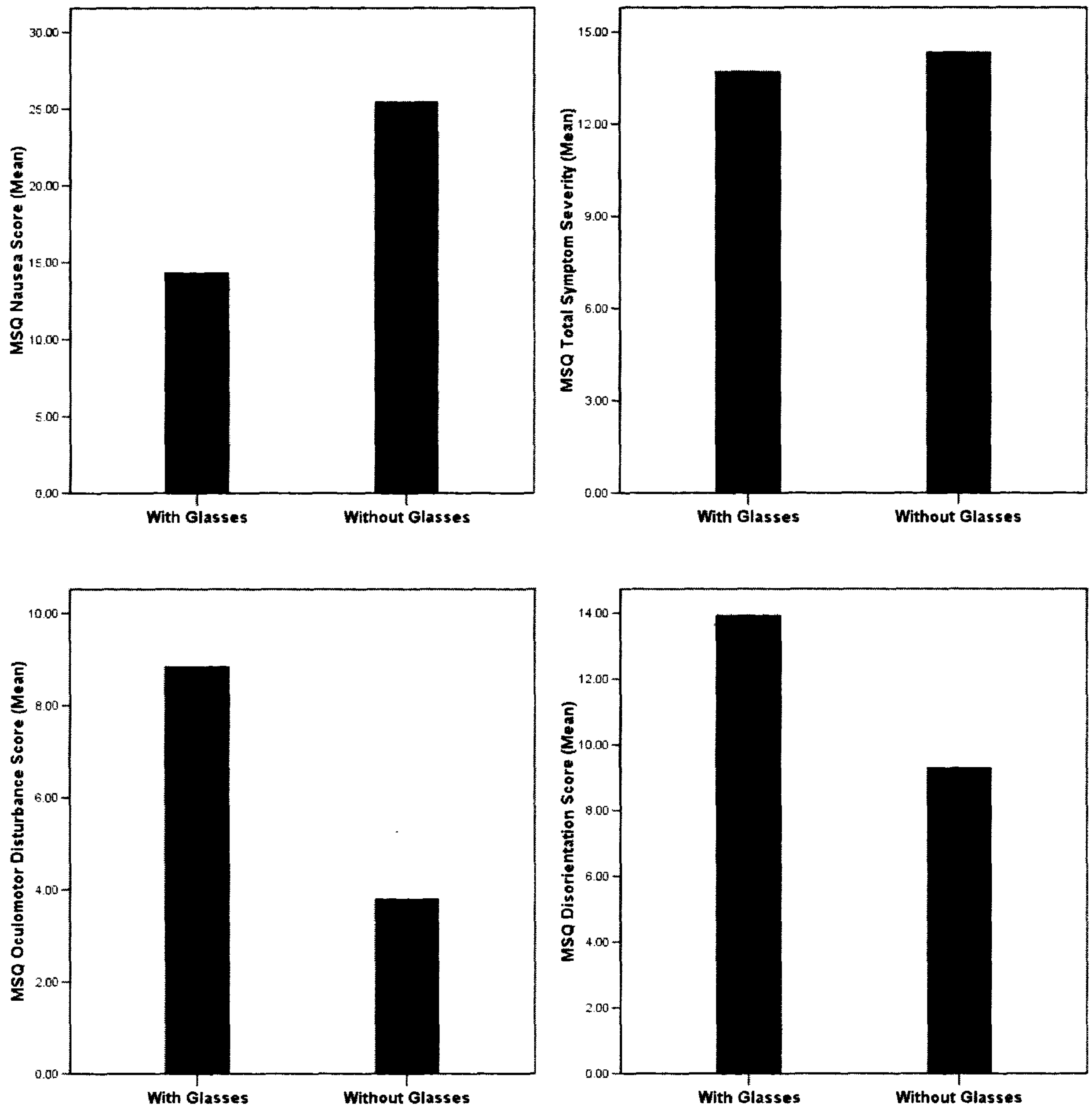

Figure 2. MSQ results: glasses versus no glasses.

Table 2.
Frequencies of MSQ symptoms reported.

MSQ Symptoms	Frequencies of Symptom Report			
	Without Glasses (N=6)	With Either 4 or 8 Hz Glasses (N=6)	With 4 Hz Glasses (N=3)	With 8 Hz Glasses (N=3)
General Discomfort * #	1 slight	2 slight	2 slight	0
Fatigue #	0	0	0	0
Boredom	1 slight	1 slight	0	1 slight
Drowsiness	0	0	0	0
Headache #	0	0	0	0
Eyestrain #	0	1 slight	1 slight	0
Difficulty Focusing # §	0	1 slight 1 moderate	1 moderate	1 slight
Increased Salivation *	1 moderate	1 slight	1 slight	0
Decreased Salivation	0	0	0	0
Sweating *	2 slight	3 slight	2 slight	1 slight
Nausea * §	3 slight 1 moderate	2 slight	2 slight	0
Difficulty Concentrating * #	2 slight	0	0	0
Mental Depression	0	0	0	0
Fullness of the head §	0	0	0	0
Blurred Vision # §	0	1 yes	1 yes	0
Dizziness with Eyes Open §	0	0	0	0
Dizziness with Eyes Closed §	0	0	0	0
Vertigo §	0	0	0	0
Visual Flashbacks	0	0	0	0
Faintness	0	0	0	0
Awareness of Breathing	1 yes	0	0	0
Stomach Awareness *	3 yes	2 yes	2 yes	0
Loss of Appetite	0	0	0	0
Increased Appetite	0	0	0	0
Desire to Move Bowels	0	0	0	0
Confusion *	0	0	0	0
Burping	2 yes	1 yes	1 yes	0
Vomiting	1 yes	0	0	0

* = combined to produce the Nausea Score
# = combined to produce the Oculomotor Score
§ = combined to produce the Disorientation Score

Comparing the glasses

When the MSQ data are compared relevant to the frequency of the stroboscopic shutter, the difference is notable (Figure 3). In this limited sample, the 8 Hz version clearly outperformed the 4 Hz, producing lower average scores in all measures of the MSQ. Previous vision-reversal studies by Melvill-Jones and Mandl (1981) and Reschke, Somers, and Ford (2006), using a 4 Hz flash, demonstrated the absence of or reduction in motion sickness symptoms. Flashing at 8 Hz may provide further reductions in motion-dynamic environments.

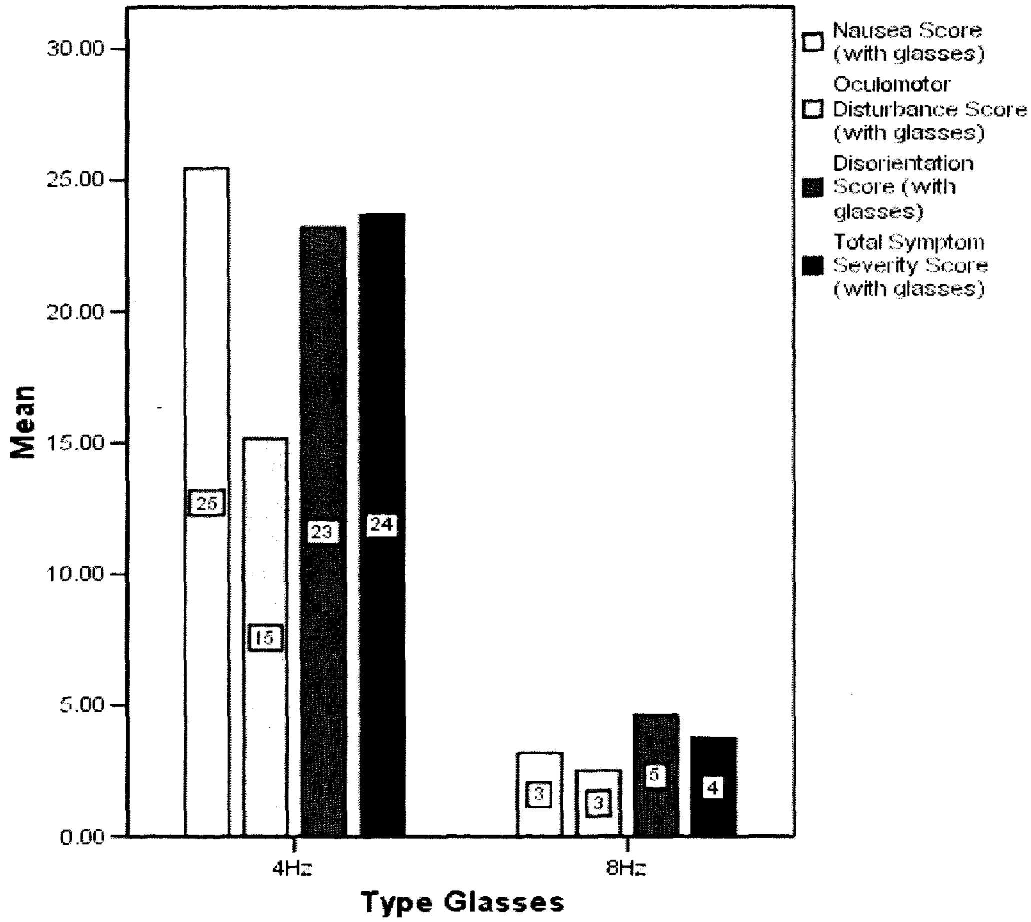

Figure 3. 4 Hz versus 8 Hz type glasses: differences in individual MSQ subscores.

Figures 4 through 7 presents each shutter glass type compared to its no glasses condition for each of the MSQ measures. What becomes evident from these comparisons is that the 4 Hz shutter glasses accounted for most of the high scores seen in Figure 2 when the aggregate glasses condition was compared to the no glasses condition, specifically the oculomotor disturbance and the disorientation measures (see Figures 5 and 6).

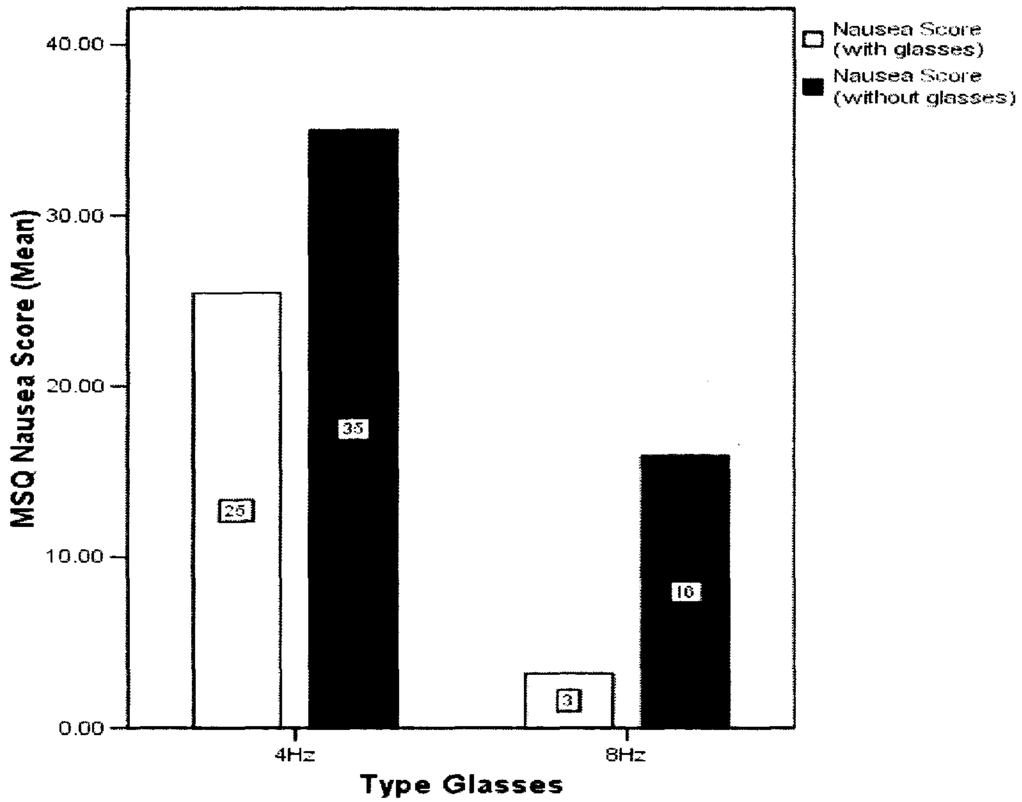

Figure 4. Mean MSQ nausea scores.

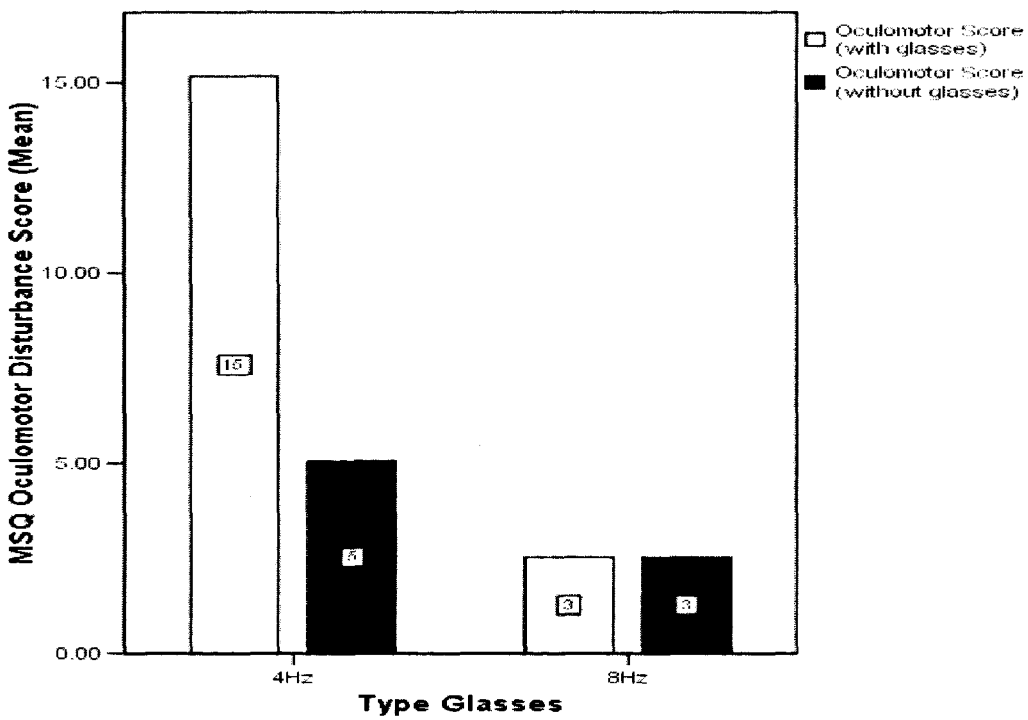

Figure 5. Mean MSQ oculomotor disturbance scores.

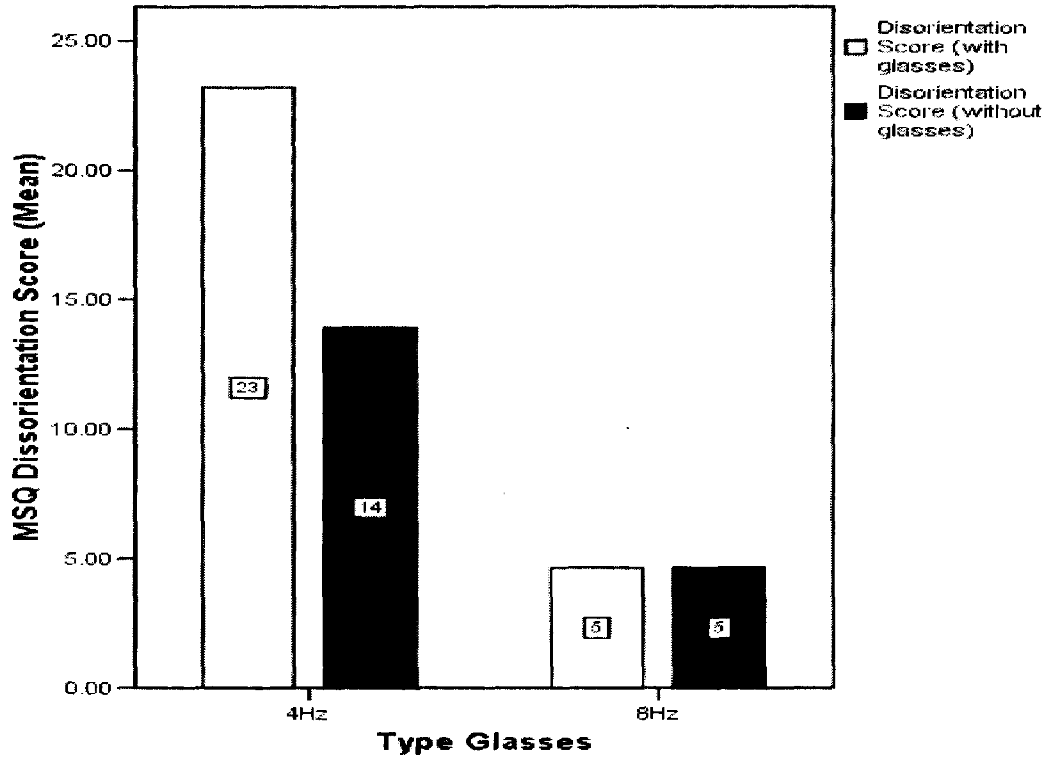

Figure 6. Mean MSQ disorientation scores.

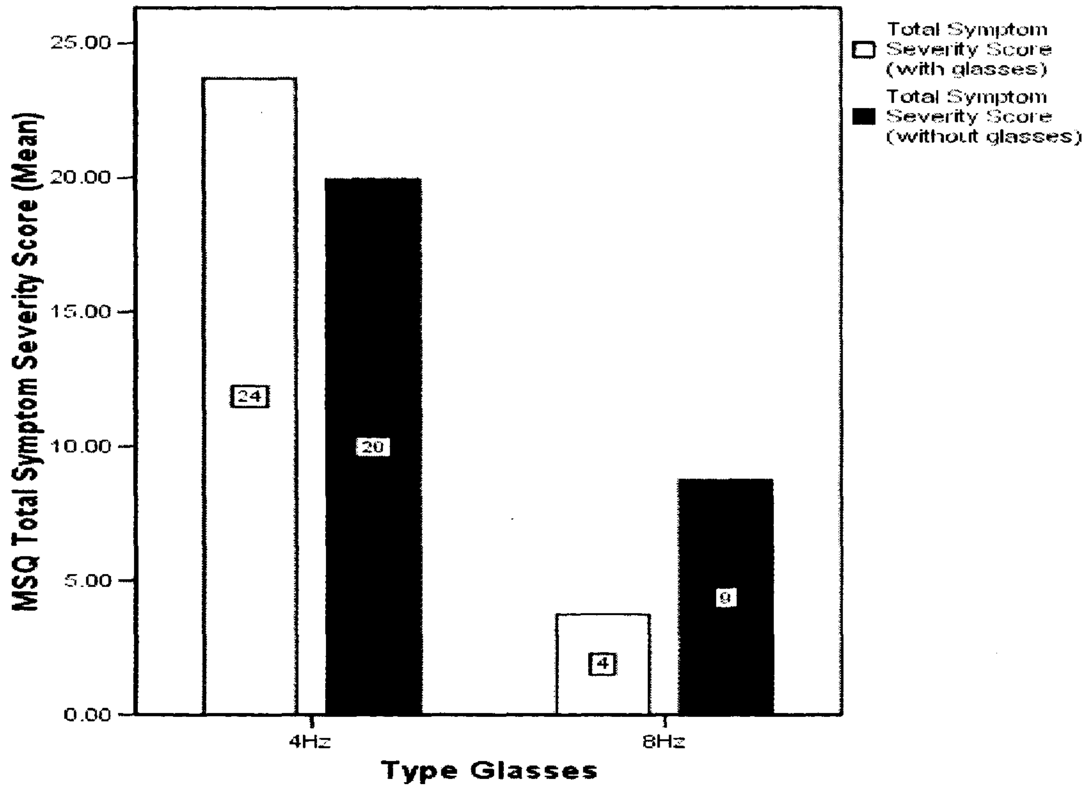

Figure 7. Mean MSQ total symptom severity scores.

Shutter Glasses Subjective Survey

The Survey findings are presented in Table 3 and can be summarized as generally positive remarks supporting further investigation into the efficacy of shutter glasses. Negative remarks included visual impairments (difficulty seeing targets, horizon, and text) and the potential to slow reaction time.

Table 3.
Results of the Shutter Glasses Subjective Survey.

1. Based on your experience wearing the glasses during this flight, do you feel that the shutter glasses were effective at controlling airsickness <u>and</u> allowing you to perform the reading tasks? 4 Hz: **Participant 1**: I had trouble reading small font with the glasses on. When sunlight hit the sheet I could read better. The flickering was a bit bothersome. Also had to look towards bottom of glass – thought maybe the top were [sic] fogging up from heat and sweat. **Participant 2**: Yes, I felt more in control. **Participant 3**: I did not feel airsickness at all while wearing the glasses. The glasses where [sic] not a problem while performing the reading task. 8 Hz: **Participant 4**: Yes. **Participant 5**: Yes. **Participant 6**: Yes, they were.
2. Based on your experience wearing the glasses during this flight, do you feel these glasses have a practical application for military helicopter passengers? 4 Hz: **Participant 1**: It's possible. Maybe with someone who has a problem with air sickness. **Participant 2**: Yes, the glasses makes [sic] you feel like everything is going slowly. **Participant 3**: The glasses will have a practical application if can [sic] be proven effective as an airsickness countermeasure. 8 Hz: **Participant 4**: Yes. **Participant 5**: Yes. **Participant 6**: For those that have problems with air sickness I do [sic].
3. Based on your experience wearing the glasses during this flight, do you feel that the shutter glasses would be an effective airsickness countermeasure for Soldiers enroute to a target? 4 Hz: **Participant 1**: For those who have a problem with it. **Participant 2**: Yes, but could slow Soldiers to react in some situations. **Participant 3**: I can subjectively say that the glasses could be an effective airsickness countermeasure, particularly during flight maneuvers. 8 Hz: **Participant 4**: Yes. **Participant 5**: Yes. **Participant 6**: Yes.

4. Based on your experience wearing the glasses during this flight, do you feel that the shutter glasses should be one of the airsickness countermeasures tested as part of the next USAARL airsickness study? 4 Hz: **Participant 1**: Yes. **Participant 2**: Yes. **Participant 3**: Yes. 8 Hz: **Participant 4**: Yes. **Participant 5**: Yes. **Participant 6**: I do think it would benefit the Army.
5. Provide any additional comments. 4 Hz: **Participant 1**: A possible thought is testing those who have previously been air sick in an aircraft and testing that population?! Just a thought. **Participant 2**: (No comment.) **Participant 3**: Although not to a significant degree, I felt more comfortable while flying with the glasses than without them. This is true particularly in situations where I was not performing the reading task and loosing [sic] the horizon reference. As a remark, while performing the reading task, I felt no motion or motion discomfort whatsoever with or without the glasses. 8 Hz: **Participant 4**: I was very surprised how well I could effectively read. The [sic] also helped me concentrate more on the text and less on the actual flight maneuvers. **Participant 5**: I think they might make target detection a bit difficult but would control sickness. **Participant 6**: There was difficulty seeing the horizon and fine ground details during flight.

Limitations

The preliminary testing of the shutter glasses was conducted to reveal their potential as a countermeasure for motion sickness in a helicopter application and to, therefore, determine their worthiness of further study. For these reasons, the preliminary testing was intentionally limited to two flights with six participants (only three per device) with no intentions of drawing firm conclusions as to the shutter glasses' efficacy.

Conclusions

The findings of this limited test provide encouragement and support for the scientific testing of stroboscopic shutter glasses, particularly the 8 Hz version, in future USAARL motion sickness mitigation studies. Although efficacy of the shutter glasses as a countermeasure for motion sickness is not implied by this test, the results do indicate that stroboscopic technologies, such as the shutter glasses, demonstrate promise and should be explored as a non-pharmacological motion sickness prevention strategy. These preliminary, but suggestive, results are consistent with other encouraging reports (Reschke, Somers, and Ford, 2006; Han et al., 2005) demonstrating that stroboscopic illumination appears to be an effective countermeasure where retinal slip is a significant factor in eliciting motion sickness. The application of shutter glasses for use by helicopter passengers, if shown to be effective, could have an overall positive impact on the operational (physical and cognitive) capabilities of warfighters transported by air.

Suggestions for future research

Future USAARL research should include stroboscopic devices, particularly the 8 Hz shutter glasses, in order to determine efficacy and to document possible unfavorable disorienting and oculomotor disturbance effects.

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Appendix A.

Manufacturer's List

MacNaughton, Incorporated
1815 NW 169th Place, Suite 3060
Beaverton, OR 97006
(503) 614-9000
Fax (503) 614-9100
boydm@nuvision3d.com
http://www.nuvision3d.com/

Appendix B.

Motion sickness questionnaire

For each symptom, please circle the rating that applies to you **RIGHT NOW**.

	1	2	3	4
General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Boredom	None	Slight	Moderate	Severe
Drowsiness	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eye Strain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Increased salivation	None	Slight	Moderate	Severe
Decreased salivation	None	Slight	Moderate	Severe
*Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
Mental depression	No	Yes		
"Fullness of the head"	No	Yes		
Blurred vision	No	Yes		
Dizziness with eyes open	No	Yes		
Dizziness with eyes closed	No	Yes		
Vertigo	No	Yes		
**Visual flashbacks	No	Yes		
Faintness	No	Yes		
Aware of breathing	No	Yes		
***Stomach awareness	No	Yes		
Loss of appetite	No	Yes		
Increased appetite	No	Yes		
Desire to move bowels	No	Yes		
Confusion	No	Yes		
Burping	No	Yes		
Vomiting	No	Yes		

Other: please
specify____

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* Sweating "Cold sweats" due to discomfort not due to physical exertion.
** Visual flashback – Illusion of movement or false sensation similar to aircraft dynamics when not in the simulator or aircraft.
*** Stomach Awareness – used to indicate a feeling of discomfort just short of nausea.

Appendix C.

Shutter Glasses Subjective Survey

1. Based on your experience wearing the glasses during this flight, do you feel that the shutter glasses were effective at controlling airsickness **and** allowing you to perform the reading tasks?

2. Based on your experience wearing the glasses during this flight, do you feel these glasses have a practical application for military helicopter passengers?

3. Based on your experience wearing the glasses during this flight, do you feel that the shutter glasses would be an effective airsickness countermeasure for Soldiers enroute to a target?

4. Based on your experience wearing the glasses during this flight, do you feel that the shutter glasses should be one of the airsickness countermeasures tested as part of the next USAARL airsickness study?

5. Provide any additional comments.

Appendix D.

Flight profile

Man #	Maneuver Description	Headings	Altitude (FEET)	Airspeed
Notes:	**Ensure blackout curtains are in place.**			
	Turn SAS - OFF before takeoff.			
1	Straight Climb (Upwind) - Allow acft to PR&Y with inputs	Hdg 030 or 210	0' AGL -> 1000' MSL	0 -> 80
2	LCT (450 degrees to Crosswind) - Vary climb rate	Hdg 030 or 210 -> Hdg 300 or 120	1000' MSL -> 1500' MSL	80
3	RDT (360 degrees) - Vary descent rate	Hdg 300 or 120 -> Hdg 300 or 120	1500' MSL -> 1000' MSL	80
4	LDT (450 degrees to Downwind) - Vary descent rate	Hdg 300 or 120 -> Hdg 210 or 030	1000' MSL -> 500' MSL	80
5	RCT (360 degrees) - Vary climb rate	Hdg 210 or 030 -> Hdg 210 or 030	500' MSL -> 1500' MSL	80
6	Straight Flight (Downwind) - Allow acft to PR&Y with inputs	Hdg 030 or 210	1500' MSL	80
7	LDT (450 degrees to Base) - Vary descent rate	Hdg 210 or 030 -> Hdg 120 or 300	1500' MSL -> 1000' MSL	80
8	RDT (270 degrees to Final) - Vary descent rate	Hdg 120 or 300 -> Hdg 030 or 210	1000' MSL -> 500' MSL	80
9	Straight Descent to touchdown - Allow acft to PR&Y with inputs	Hdg 030 or 210	500' MSL -> 0' AGL	80 -> 0

Note: Repeat two times.

Flight Profile Glossary

AGL – Above ground level. Hdg – heading. LCT – Left climbing turn. LDT – Left descending turn. MSL – Mean sea level. PR&Y – Pitch, roll, and yaw. RCT – Right climbing turn. RDT – Right descending turn. SAS – Stability Augmentation System.

Appendix E

Reading task sheets

A

TM 1-1520-237-CL

EXTERNAL EXTENDED RANGE FUEL SYSTEM FAILURE TO TRANSFER SYMMETRICALLY. ERFS

If asymmetric fuel transfer is suspected:

1. Stop transfer on tank set.
2. Select other tank set and initiate transfer.
3. LAND AS SOON AS PRACTICABLE.

Should controlled flight with one heavy external tank become necessary, proceed as follows:

1. Make all turns shallow (up to standard rate), and in the direction away from heavy side (particularly when a right tank remains full).

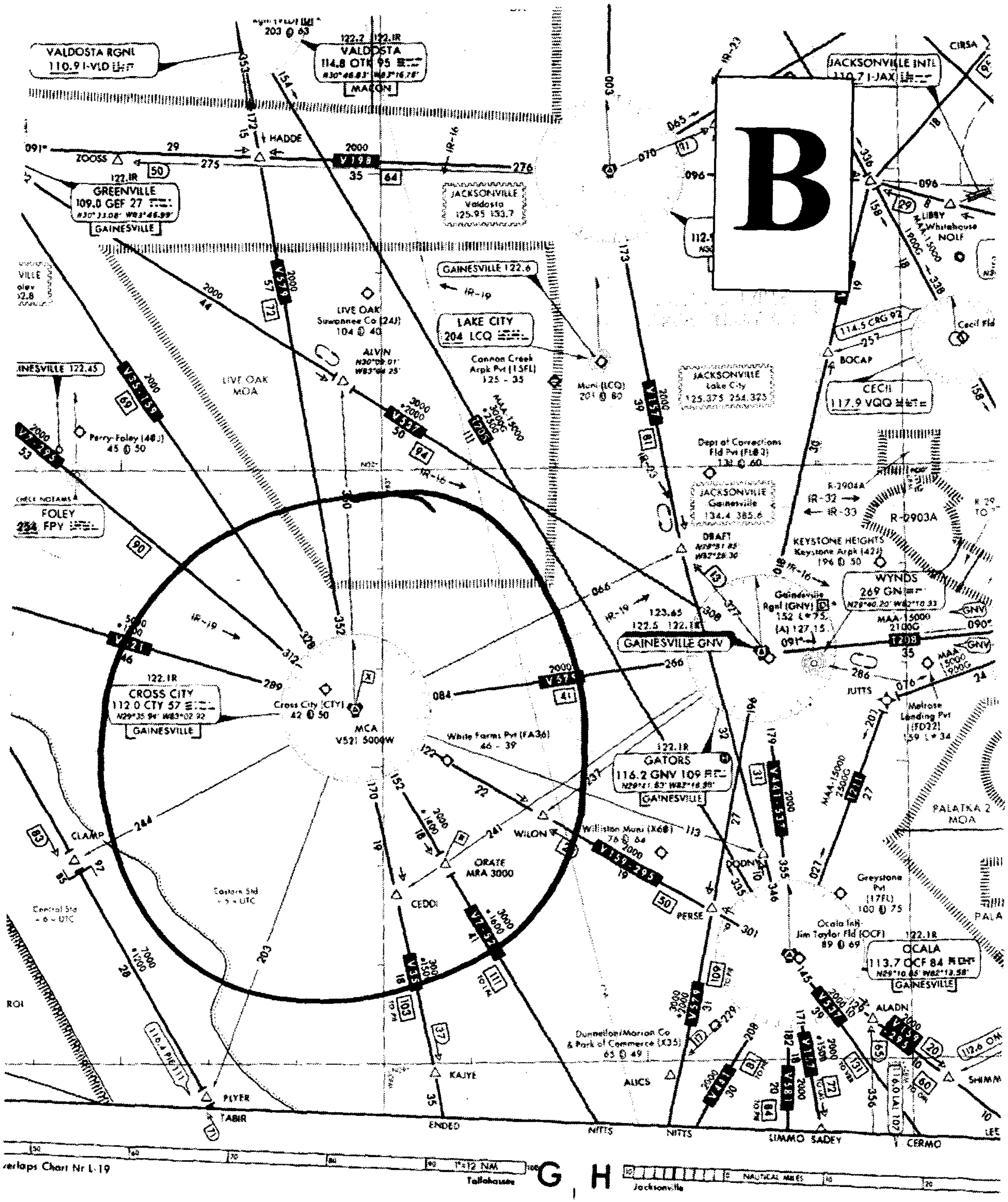
2. Avoid abrupt control motions, especially lateral cyclic.

3. If possible, shift personnel to the light side of the helicopter.

4. Select a suitable roll-on landing area, and make a roll-on landing with touchdown speed in excess of 30 KIAS. To increase control margin, execute the approach into the wind or with a front quartering wind from the heavy side and align the longitudinal axis of the aircraft with the ground track upon commencing the approach. If a suitable roll-on landing area is not available, make an approach to a hover into the wind, or with a front quartering wind from the heavy side.

E-32

B


VALDOSTA RGNL
110.9 I-VLD
VALDOSTA
114.8 OTK 95
MACON
JACKSONVILLE INTL
JACKSONVILLE
Valdosta
125.95 133.7
GREENVILLE
109.0 GEF 27
GAINESVILLE
GAINESVILLE 122.6
LAKE CITY
204 LCQ
LIVE OAK
Suwannee Co (24J)
104 40
ALVIN
LIVE OAK MOA
JACKSONVILLE
Lake City
125.375 254.325
JACKSONVILLE
Gainesville
134.4 385.6
CECIL
117.9 VQQ
BOCAP
KEYSTONE HEIGHTS
Keystone Arpk (42J)
196 50
WYNDS
269 GN
R-2903A
GAINESVILLE GNV
FOLEY
FPY
CROSS CITY
112.0 CTY 57
Cross City (CTY)
42 50
MCA
V521 5000W
White Farms Pvt (FA36)
46 - 39
GATORS
116.2 GNV 109
WILON
Williston Muni (X60)
76 64
ORATE
MRA 3000
CEDDI
PERSE
CLAMP
OCALA
113.7 OCF 84
Ocala Intl-
Jim Taylor Fld (OCF)
89 69
Greystone
Pvt
(17FL)
100 75
PALATKA 2
MOA
Melrose
Landing Pvt
(FD22)
JUTTS
ALADN
Dunnellon/Marion Co
& Park of Commerce (X35)
65 49
ALICS
KAJYE
PLYER
TABIR
ENDED
NITTS
LIMMO
SADEY
CERMO
Overlaps Chart Nr L-19
Tallahassee
G
H
Jacksonville
NAUTICAL MILES

% TRQ SPLIT BETWEEN ENGINES 1 AND 2.

1. If **TGT TEMP** of one engine exceeds the limiter(700 852°C, 701C 875°C with low power engine above 50% **TRQ**or 901°C with low power engine below 50% **TRQ**), retard **ENG POWER CONT** lever on that engine to reduce **TGT TEMP**. Retard the **ENG POWER CONT** lever to maintain torque of the manually controlled engine at approximately 10% below the other engine.

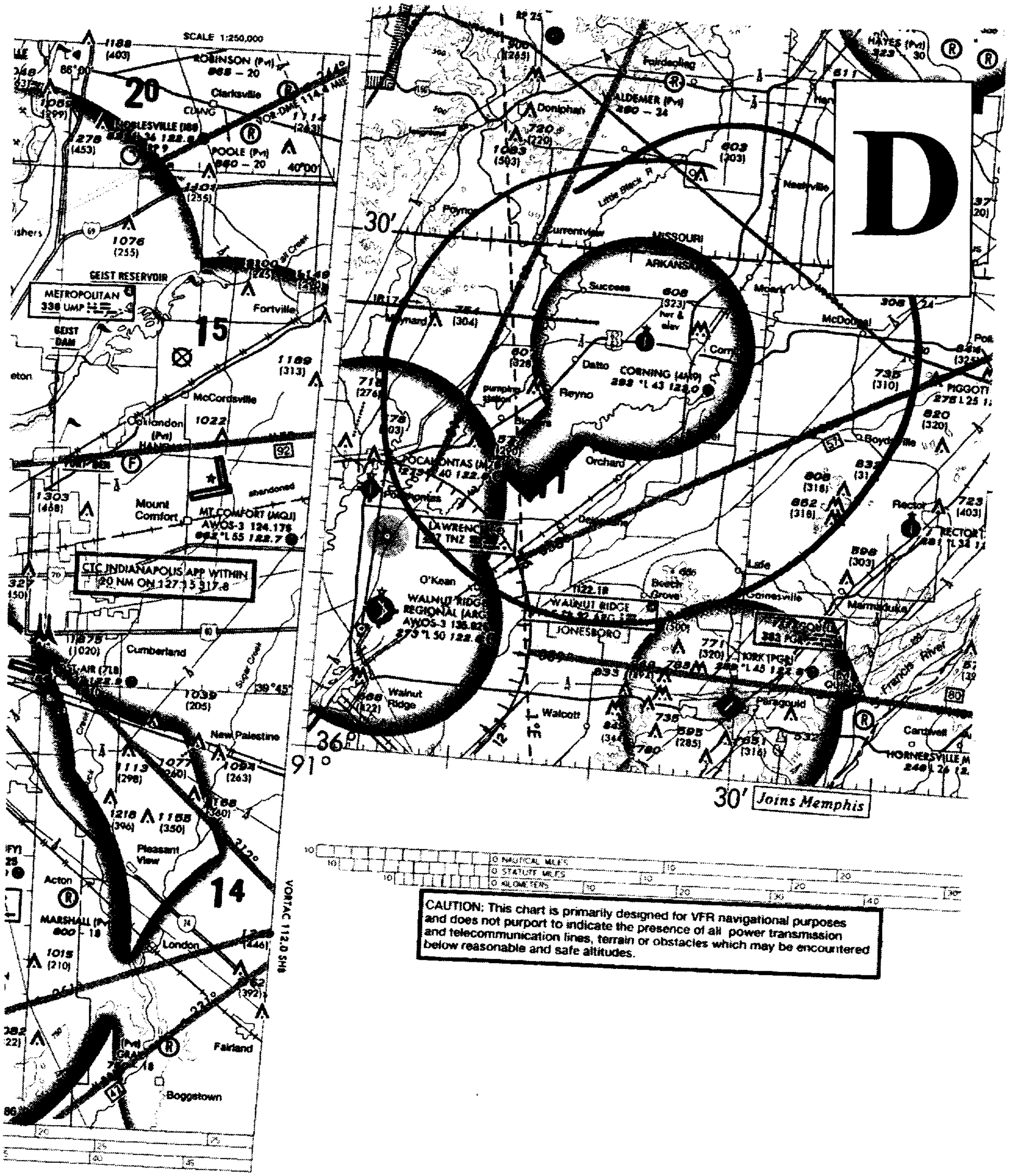
2. If **TGT TEMP** limit on either engine is not exceeded, slowly retard **ENG POWER CONT** lever on high **% TRQ** engine and observe **% TRQ** of low power engine.

3. If **% TRQ** of low power engine increases, **ENG POWER CONT** lever on high power engine - Retard to maintain **% TRQ** approximately 10% below other engine (the high power engine has been identified as a high side failure).

4. If **% TRQ** of low power engine does not increase, or **% RPM R** decreases, **ENG POWER CONT** lever - Return high power engine to **FLY** (the low power engine has been identified as a low side failure).

5. If additional power is required, low power **ENG POWER CONT**lever, momentarily move to **LOCKOUT** and adjust to set **% TRQ** approximately 10% below the other engine.

6. LAND AS SOON AS PRACTICABLE.


D
SCALE 1:250,000
Clarksville
GEIST RESERVOIR
METROPOLITAN
Fortville
McCordsville
abandoned
Mount Comfort
MT COMFORT (MQJ)
CTC INDIANAPOLIS APP WITHIN 20 NM ON 127.15 317.8
Cumberland
Sugar Creek
New Palestine
Pleasant View
Acton
London
Fairland
Boggstown
Doniphan
Little Black R
Currentview
MISSOURI
ARKANSAS
Success
CORNING (4M9)
Datto
Reyno
Orchard
O'Kean
WALNUT RIDGE
JONESBORO
Walnut Ridge
Walcott
Paragould
Lafe
Gainesville
Marmaduke
Nashville
McDougal
Rector
PIGGOTT
Francis River
Cardwell
HORNERSVILLE
Joins Memphis
NAUTICAL MILES
STATUTE MILES
KILOMETERS
CAUTION: This chart is primarily designed for VFR navigational purposes and does not purport to indicate the presence of all power transmission and telecommunication lines, terrain or obstacles which may be encountered below reasonable and safe altitudes.

E

Section V FLIGHT CONTROLS

2.36 FLIGHT CONTROL SYSTEMS.

NOTE

Flight near high power RF emitters such as microwave antennas or shipboard radar may cause uncommanded AFCS and/or stabilator control inputs. Electromagnetic interference (EMI) testing has shown that the master caution may appear before or simultaneously with any uncommanded stabilator trailing edge movement, with 4° or 5° of movement being the maximum.

The primary flight control system consists of the lateral control subsystem, the longitudinal control subsystem, the collective pitch control subsystem, and the directional control subsystem. Control inputs are transferred from the cockpit to the rotor blades by mechanical linkages and hydraulic servos. Pilot control is assisted by stability augmentation system (SAS), flight path stabilization (FPS), boost servos, and pitch, roll, and yaw trim. Dual cockpit controls consist of the cyclic stick, collective stick, and pedals. The pilot and copilot controls are routed separately to a combining linkage for each control axis. Outputs from the cockpit controls are carried by mechanical linkage through the pilot-assist servos to the mixing unit. The mixing unit combines, sums, and couples the cyclic, collective, and yaw inputs. It provides proportional output signals, through mechanical linkages, to the main and tail rotor controls.

2.36.1 Cyclic Stick. Lateral and longitudinal control of the helicopter is by movement of the cyclic sticks through pushrods, bellcranks, and servos to the main rotor. Movement in any direction tilts the plane of the main rotor blades in the same direction, thereby causing the helicopter to go in that direction. Each cyclic stick grip (Figure 2-14) contains a stick trim switch marked **STICK TRIM FWD**, **L**, **R**, and **AFT**, a go-around switch marked **GA**, trim release switch marked **TRIM REL**, a panel light kill switch marked **PNL LTS**, a cargo release switch marked **CARGO REL**, and a transmitter **ICS** switch marked **RADIO** and **ICS**.

2.36.2 Collective Pitch Control Stick. The collective sticks change the pitch of the main rotor blades, causing an increase or decrease in lift on the entire main rotor disc. A friction control on the pilot's lever can be turned to adjust the amount of friction and prevent the collective stick from creeping. The copilot's stick telescopes by twisting the grip and pushing the stick aft to improve access to the seat. Each collective stick has a grip (Figure 2-14) with switches and controls for various helicopter systems. These systems are: landing light control marked **LDG LT PUSH ON/OFF**, **EXT**, and **RETR**, searchlight controls marked **SRCH LT ON/OFF**, **BRT**, **DIM**, **EXT**, **L**, **R**, and **RETR**, servo shutoff control switch marked **SVO OFF 1ST STG** and **2ND STG**, engine speed trim switch marked **ENG RPM INCR** and **DECR**, and cargo hook emergency release switch marked **HOOK EMER REL**, **HUD** control switch marked **BRT**, **DIM**, **MODE**, and **DCLT**. All switches are within easy reach of the left thumb.

2.36.3 Mixing Unit. A mechanical mixing unit provides control mixing functions which minimizes inherent control coupling. The four types of mechanical mixing and their functions are:

a. Collective to Pitch - Compensates for the effects of changes in rotor downwash on the stabilator caused by collective pitch changes. The mixing unit provides forward input to the main rotor as collective is increased and aft input as collective is decreased.

b. Collective to Yaw - Compensates for changes in torque effect caused by changes in collective position. The mixing unit increases tail rotor pitch as collective is increased and decreases tail rotor pitch as collective is decreased.

c. Collective to Roll - Compensates for the rolling moments and translating tendency caused by changes in tail rotor thrust. The mixing unit provides left lateral input to the main rotor system as collective is increased and right lateral input as collective is decreased.

d. Yaw to Pitch - Compensates for changes in the vertical thrust component of the canted tail rotor as tail rotor pitch is changed. The mixing unit provides aft input to the main rotor system as tail rotor pitch is increased and forward input as tail rotor pitch is decreased.

2.36.4 Collective/Airspeed to Yaw (Electronic Coupling). This mixing is in addition to collective to yaw mechanical mixing. It helps compensate for the torque effect caused by changes in collective position. It has the ability to decrease tail rotor pitch as airspeed increases and the tail rotor and cambered fin become more efficient. As airspeed decreases, the opposite occurs. The SAS/FPS computer commands the yaw trim actuator to change tail rotor pitch as collective position changes. The amount of tail rotor pitch change is proportional to airspeed. Maximum mixing occurs from 0 to 40 knots. As airspeed